Geovisualisation and Spatio-Temporal Modelling from Satellite Imagery: A Study of Million+ City, Ghaziabad, NCR Region, India.

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Abstract. The urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. Urban sprawl has been quantified by considering the built-up area as the key feature of sprawl, which can be obtained either from physical field survey or through remote sensing satellite imagery. A large number of studies are dealing with quantification of the spatial patterns of urban sprawl with the help of Remote Sensing and GIS. In all these studies, however, concluded with different methodologies in quantifying the urban sprawl. But it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial pattern of urban sprawl. So, the urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. In the recent past, a lot of attention has been paid to understand and analyze the process of spatial patterns of urban sprawl. It is noteworthy to mention that over the periods, there has been a continuous process of urban sprawl in the rural-urban fringe of Ghaziabad City due to the liberalization of economy, development plans and policies of the State Govt. of Uttar Pradesh and Central Govt. of India.

Keywords: Geovisualisation, Remote Sensing, Urban Sprawl, Economic Development, Development Plans and Policies.

1. Introduction

Urban Sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. In the recent past, a lot of attention has been paid to understand and analyze the process of spatial patterns of urban sprawl. A large number of studies are dealing with quantification of the spatial patterns of urban sprawl (Couch et. al. 2005, Sultana & Weber 2007, Bruegmann 2006, Siedentop 2010). In all these studies, however, concluded with different methodologies in quantifying the urban sprawl. But it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial patterns of urban sprawl. Due to the continuous in-migration of peoples from the countryside's, the urban areas continue to expand over the periods. This process of urbanization emphasizes that once a direction of urban growth picks up momentum, it becomes very difficult to reduce sprawl in spite of the fact that sites may not be entirely suitable for expanding a new town.

In view of this, the conventional surveying and mapping techniques are expensive and time consuming for the estimation of urban sprawl. Such information is not easily available for most of the urban centers and cities. So, as a result, increasing research interest is being directed to the mapping and monitoring of urban sprawl using geospatial technologies which is best suited for geovisualiation of spatio-temporal land development as well as for modelling of the process of urban sprawl. Remote sensing is cost effective technology and is increasingly being used for the impact analysis of urban sprawl (Jat et. al. 2008, Xia & Anthony 2007). During the past, for more than three decades, extensive research efforts have been made for urban change detection using Remote Sensing Satellite Imagery and Geographic Information Systems for impact analysis assessment of urban sprawl (Rodriguez-Buchiller 2004, Xia Li & Anthony 2004, Yang and Lo 2003).

In lieu of this, the present study has considered the urban sprawl as a challenging task therefore, seeks to bring out the noteworthy impacting factors of the process of urban sprawl. Besides this, Urban sprawl has been quantified by considering the built-up area as the key feature of sprawl, which can be obtained either from physical field survey or through remote sensing satellite imagery. Over the periods, there has been a continuous process of urban sprawl in the rural-urban fringe of Ghaziabad City due to the extension of transport network corridors, liberalization of economy, development plans and policies of the state govt. of Uttar Pradesh and Central Govt. of

India. It has resulted into the establishments of number of national and multinational companies, since the inception of Ghaziabad as an industrial city. So, it is noteworthy to mention that there has been occurred a continuous urban sprawl in the rural-urban fringe of the Ghaziabad City. It has largely been responsible in the transformation of physical landscape which is creating socio-economic and environmental concerns. Hence, the present research would make an attempt to help local, regional and state level land use planners and policy makers to better understand and address the issues attributed to urban sprawl.

2. Conceptual Framework on Urban Sprawl

In the recent past, a lot of attention has been paid to understand and analyse the process of spatial patterns of urban sprawl. Studies are dealing in-depth with considerable progress in quantifying the spatial patterns of urban sprawl (Yeh and Li 2001, Epstein & Kramer 2002). The urban sprawl consists of three basic spatial forms as the low-density sprawl, ribbon sprawl and leapfrog development sprawl (Yeh and Li 2001, Yang & Lo 2003, Shannon 1948). An increasing pace of urbanisation is usually associated with and driven by the population concentration in an area over the periods. The extent of urbanization drives the change in land use patterns. Exact information on the extent of urban growth is of great interest for the development authorities of growing urban and suburban areas for diverse purposes such as urban planning, water and land resource management, and infrastructure and amenities development (Wolman et. al. 2005).

Urban development authorities and municipal corporations are required to devote more time, attention and effort to manage land use and other resources for accommodating the expanding population. Urban sprawl monitoring is the basic information for the development authorities for formulation of long term planning and policies (Cho 2005, Wood 2007). Although the debate over whether a “sprawling” urban form is best for the quality of city life has not been fully settled. There are number of dimensions of sprawl such as the density, continuity, concentration, clustering, centrality, mixed uses, and proximity which were considered for urban sprawl. Urban green spaces have important amenity values that include provision of leisure opportunities and aesthetic enjoyment. So, they are usually ignored or underestimated by urban planning policy-makers, with the result that remnant urban green spaces are being gradually encroached upon by urban sprawl.

3. Objectives and Research Questions

The main objectives of the present study are mentioned as follows:

i. to analyse the spatio-temporal patterns of urban land use;
ii. to identify the spatial patterns of urban built-up lands;
iii. to see the process of urban land use transformation;
iv. to suggest and recommend suitable strategies for sutainable urban land use development.

The present study has enquired the process of urban sprawl which is a challenging task for the urban planners therefore, seeks to answers a number of research questions in detail as given below:

i. What are the geospatial patterns of land use changes during 2001 to 2011?
ii. What are the forms and patterns of urban sprawl exists over the periods?
iii. Which are the impacting factors responsible for the urban sprawl?
iv. What are the most suitable strategies for sustainable urban development?

So, the present research has made an attempt to help local, regional and state level land use planners and policy makers to better understand and address the issues attributed to urban sprawl.

4. Database of the Study

The present study is taking into account the urban sprawl analysis for the million+ Ghaziabad City of the NCR Region which has particularly and largely been impacted by the expansion of the transport network corridors. In context to quantative methods, the random stratified sampling method seems to be best suited for extraction of samples from the primary field survey for measurement of the process of urban sprawl. For the million+ Ghaziabad City, a sample size of 33 per cent from different strata of the society has been collected for generalisation and analyses of the impacting factors of urban sprawl. The GPS system with higher accuracy has been used in collection and generation of the real time frame work geographical data in the form of the ground controlling points (GCP), the ground truth (field verification) sample data and the real time field boundary mapping of urban centres and for assessment of the process of urban sprawl from the selected sample sites from the field for the Ghaziabad City.

Besides this, the open series topographic sheets on the scale of 1:25,000 (quarter inch sheets) have been acquired to extract boundary maps and

other relevant spatial layers information at the various levels. These digital topographic sheets have been obtained from the Survey of India, Dehradun. The multispectral digital imagery of the IRS series of satellites was procurred from the National Remote Sensing Centre (NRSC), Hyderabad, India. The high resolution multispectral digital imagery of the Landsat satellites have also been obtained from the United States Geological Survey (USGS) website. In addition to this, the high resolution (2-meter resolution) satellite imagery of the Cartosat-2 has also been obtained from the National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), Department of Space (DOS), Govt. of India, Hyderabad, India. The details of the satellite imagery used in the present study is given in the *Table-1* below:

Date of Acquisition	Satellite	Sensor	Spatial Resolution (in meters)	No of Spectral Bands	No. of Spectral Bands Used	Wavelength (in micrometers)
1972	Landsat-2	MSS	80	4	4, 5, 6	0.5-0.6|0.6-0.7|0.7-0.8
1975	Landsat-3	MSS	80	4	4, 5, 6	0.5-0.6|0.6-0.7|0.7-0.8
1989	Landsat-5	TM	28.5	7	2, 3, 4	0.52-0.60|0.63-0.69|0.76-0.90
1997	IRS-1C	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
1999	Landsat-7	ETM+	28.5	7	2, 3, 4	0.52-0.60|0.63-0.69|0.76-0.90
		PAN	14.5	1	8	0.52-0.90
2001	IRS-1D	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
2006	IRS-P6	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
2009	Landsat-5	TM	28.5	7	2, 3, 4	0.52-0.60|0.63-0.69|0.76-0.90

Notes:
Image courtesy of the U.S. Geological Survey (USGS), United States of America.
Image courtesy of the National Remote Sensing Centre (NRSC), Hyderabad, India.

Table 1. Details of the multispectral satellite imagery of Landsat and IRS Satellites.

The present study is also based on the latest data available from the secondary sources to achieve the specified objectives of the present study. There are different sources of ancillary data which are available from the

records of the Census of India 2001 and 2011 on the growth of urban population and the growth of urban centres. So, the Primary Census Abstract, Final Population Total, and the Village and Town Directory and the the Census Atlas –Ghaziabad District and Uttar Pradesh State have been used in the present study. All these government publications are readily available in print as well as digital form from the Controller of Publications, Census of India, Man Singh Road, New Delhi. In addition to this, a number of development plans and policies, records, reports and documents published by the different States and Central Government departments and ministries are also collected as the Department of Land and Development and the Department of Urban Development, Ministry of Urban Development, Govt. of India, and others.

5. Research Methodology

Urban Land Use mapping for the study area have been carried out by standard methods of analysis of remotely sensed data followed by ground truth collection, and visual interpretation of satellite imagey. The Landsat and IRS visible and infrared spectral bands as 2, 3, 4, 5, 6 & 8 have been used of which details is given in the above *Table-1*. The Digital Image Processing was carried out with the help of ERDAS Imagine software based on broadband satellite imagery. Widely used vegetation indices such as normalized difference vegetation index (NDVI) (Tucke 1979, Wiegand et al. 1991), transformed vegetation index (TVI) (Richardson & Wiegand 1977, Rouse et al. 1973), simple ratio (SR) (Jordan 1969, Maxwell 1976) and difference vegetation index (DVI) respond to these differences in the near infrared and the visible regions (Lillesand and Kiefer 1994, Schowengerdt 1983) and transformed soil adjusted vegetation index (TSAVI) have been widely used to measure vegetation quantity, leaf area index (LAI) and per cent green vegetation cover of vegetation at canopy scale (Blackburn & Steele 1999, Boegh et al. 2002, Elvidge & Chen 1995, Gao et al. 2000, Schowengerdt 1983, Tucker 1979). Although these indices have been successfully used in areas with open canopy cover or sparsely vegetated regions, they have not been successful in estimating quantity at high canopy density. Specifically, the widely used vegetation indices particularly NDVI derived from broad band satellite images such as Landsat TM tend to saturate after a certain biomass density or LAI (Gao et al. 2000, Sellers 1985, Thenkabail et al. 2000, Todd et al. 1998, Tucker 1977). So, the ERDAS Imagines' supervised classification algorithm has been used for image processing to derive the NDVI for the study.

The present study is based on the spatial and non-spatial data analyses in the ArcGIS appilcation software for geographic analysis and geospatial processing. As the proximity and network analyses modules of ArcGIS have been used for transport corridors network analysis. Besides this, the real world coordinates attribute data collected by the GPS system has been spatially visualised by its application software. So, the software's specific inbuilt mathematical/statistical methods and models have been applied for impact analyses on the process of urban sprawl.

The Shannon's Entropy Model which is empirically validated has been applied for measuring the degree of spatial concentration or dispersion of geospatial variable (Xi) among n zones (Shannon 1948, Haynes et. al. 1980, Haynes & Storeberk 1978, Joshi et. at. 2006, Yeh & Li 2001, Zhang et. al. 2006, Lo & Yeung 2005). So, finally it is defined and explained as follows:

$$S = \sum_{i=1}^{n} pi \log(1/pi)/\log(n) \quad (1)$$

Where:

$pi = xi / \sum_{i=1}^{n} xi$ and xi is the observed value in the i th zone in total of n zones.

The entropy value ranges from 0 to 1. If the distribution is maximally concentrated in one region, the lowest value zero will be obtained. Conversely, an evenly disperse distribution across space will give a maximum value of 1. The major difference between entropy and traditional indices of spatial dispersion is that its value is invariant with the value of zones, the number of observation (n).

Since the entropy can be used to measure the distribution of a geographical phenomenon, thus the measurement of the difference on entropy between time t+1 and t can be used to indicate the magnitude of change in the degree of dispersal of land development or urban sprawl. It is defined as follows:

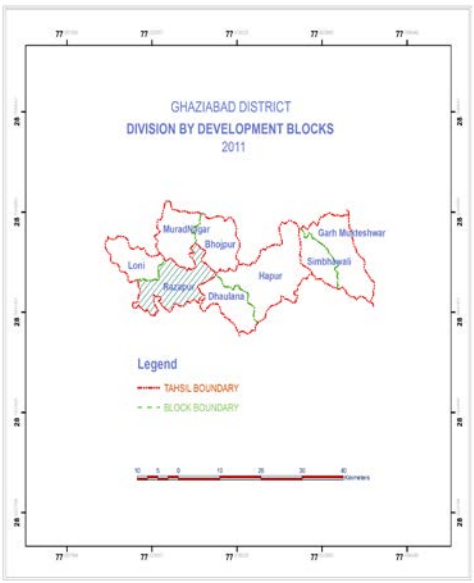
$$\Delta Sn = Sn\,(t+1) - Sn\,(t) \quad (2)$$

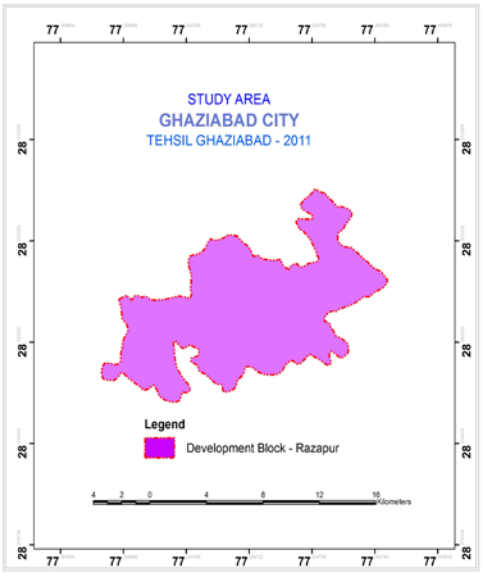
The dispersal of urban areas from a city centre will lead to an increase in the entropy value. The change of entropy can be used to identify whether land development is toward a more dispersal (sprawl) or compact pattern. So, the typical patterns of urban sprawl are categories into three classes as the concentrated (Low Development); the dispersed (Medium Develop-

ment); and the scattered (High Development). These three types of urban sprawl patterns are reflected from the entropy. The multi-spectral signatures of remote sensing and entropy model have been applied to scrutinize the geospatial and temporal land transformation caused by to the process of urban sprawl.

6. Study Area

Ghaziabad City is one of the important million+ city of the Uttar Pradesh State in the Sub-Region of NCR. It is located at about 22 kms. From the National Capital Territory (NCT) Delhi and is an important industrial and trading center in Delhi Metropolitian Area (DMA). The city is located on the Grand Trunk road and about a mile east of the Hindon River at 28^{O} 40‘ N latitude and 70^{O} 25‘ E longitude on National Highway (NH-24) connecting the city with Delhi-Mordabad-Lucknow as is evidence by the *Figure 1.* Two other National Highways i.e. NH-58, Lucknow-Varanasi passing through Niti Pass and NH-91 to Bulandshrahr also passes through the city. The State Highway (SH-57) connects the city to Baghpat and Sahaaranpur. The city is bounded by the NCT Delhi in the west and NOIDA City in the south. The geogaphical location of the million+ Ghaziabad City is presented in the *Map-1 & 2* below:





Map 1 & 2. Map1 shows the location of the study area – Ghaziabad City in the boundary map of development blocks; Map 2 shows boundary maps of the study area – Ghaziabad.

Ghaziabad as a district was declared on 14th November 1976. Ghaziabad is situated in an agricultural area in the western part of the Uttar Pradesh. From the historical, cultural, mythological and archaeological point of view, Ghaziabad has been a prosperous city. This has been proved from the research work and excavations undertaken in the district. The historical excavation work carried out at the mound of Kaseri situated on the bank of Hindon River, 2 km north from Mohan Nagar, shows that there was existed ancient civilization dated back to 2500 B.C. In terms of topography, there has been existed almost flat terrain. The average elevation is 200 m above mean sea level. The climate is dry and healthy, intensely hot during summer (May-June) temperature rises to 45^{O} C and quite cold in winter (December-January) drops to 20^{O} C. Geologically, it is the part of Indo-Gangetic alluvium, which consist of sand, clay, kankar and reh. The strata consists mainly of sandy soil which is quite fertile and loamy. The depth of sub-soil water table is about 10-15 metres below ground level and the seasonal variation is about 5 metres. It is drained by the Hindon River which finally merges in the Yamuna River.

7. Demographic Composition

7.1. Growth Trends of Population

Ghaziabad city has witnessed unprecedented growth of population especially during the last three decades. In 1911, it began as a small settlement near Delhi with a population of 11309, which grew to 23.58 lakh in 2011 as is evidenced by the *Table-2*. During 1971-2011 period, the city population recorded an increase of 16.21 times and during 2001-2011 it increased by 1.43 times. Whereas there was population growth of 143.52 per cent during 2001-2011 decade which signifies that the city's population has been growing at a very rapid pace compared to other cities of Uttar Predesh (UP) State's of the Sub-Region of NCR. As per 1981 Census, the density of Ghaziabad was 4366 persons per sq. km. which increased to 7066 persons per sq. km. in 1991. Later on, the density was declined to 6702 persons per sq. km. in 2001. This was mainly due to increase in the jurisdiction of Municipal Corporation. The area of Municipal Corporation also increased from 63.94 sq. km in 1981 to 144.50 sq. km in 2001. However, in actual terms, it is observed that as per the land use pattern, the population density is about 13070 persons per sq. km.

The rapid growth of Ghaziabad city is mainly due to vivid and multifarious reasons, which include proximity to Delhi, establishment of planned indus-

trial estates, discouragement to the establishment of large-scale industries in NCT Delhi and political stability in the UP Sub-Region of NCR. Although of late, especially during the last decade, a number of small and big industrial units in the city were closed down and retail trade could not take off as expected. However, the territory sector (services) became the biggest source of employment and thereby city experienced rapid population growth. In addition to this, there are two more reasons for the rapid growth of population as first, due to the availability of fertile land the nearby villages wherein the population desired to improve their living conditions settled down in Ghaziabad; and secondly, due to close proximity to NCT Delhi, the middle class families, which were unable to purchase houses in NCT Delhi, preferred to purchase house/land in the Ghaziabad City. All these reasons clearly reveal the prevalence of pull factors in Ghaziabad City and push factor from NCT Delhi. The majority of people settled down in Trans-Hindon area of the city and they used to work in NCT Delhi, which is an indication of growing urbanization in the DMA area and to be part of Ghaziabad Urban Agglomeration.

Year	Urban Population	Growth Rate (in per cent)	Area (in sq km)	Density (per sq km)
1901	11275	-		
1911	11304	00.26		
1921	12343	09.19		
1931	18831	52.56		
1941	23834	26.57		
1951	43745	83.54		
1961	70438	61.02		
1971	137033	94.54		
1981	287170	109.56		
1991	511759	89.25		
2001	968521	89.25		
2011	2358525	143.52		

Source: Census of India 2011, Village & Town Directory; and District Census Handbook, Ghaziabad District.

Table 2. Growth Rate and density of population in Ghaziabad City.

Furthermore, the post independence period witnessed establishment of industries and thereafter with the discouragement of large-scale industrial establishments in NCT Delhi, the city developed in all the spheres. It may be stated that till 1971 the development of city was self-induced, however, consequently due to spill over of population of NCT, Ghaziabad witnessed rapid population growth. It may be observed from the above table that during 1921-31 and 1941-51 there was sharp increase in the growth rate of population mainly due to establishment of grain markets and oil mills, breweries and administrative offices during 1930's and influx of refugees. The planned development begun in 1961, which further attracted population contributing the growth of 94.54 per cent during 1961-71 and 109.56 per cent during 1971-81 and 98.25 per cent during 1981-91. Thereafter, the growth population again showed increasing trend and recorded a phenomenal growth rate of 143.52 per cent during 2001-2011 as is evidenced by the above *Table-2*.

However, there are many factors responsible for rapid population growth as well as development of Ghaziabad which are as (i) Uttar Pradesh State Industrial Development Corporation (UPSIDC) developed industrial estates like Sahibabad, Kavinagar, Bulandshahr Road, Loni Road, Meerut Road and G.T. Road whereas Ghaziabad Development Authority (GDA) developed residential and physical infrastructure; (ii) the fertile land coupled with widespread agriculture attracted labour due to the relative prosperity and displacement of labour in surrounding rural areas which became a "push factors" for the population migrating towards an employment generating area during 1950's and 1960's; (iii) the high land values in the real estate market of NCT Delhi and availability of relatively cheaper land in Ghaziabad next to NCT Delhi; (iv) the transport corridors connecting NCT Delhi to the resource base of the Western Uttar Pradesh via Ghaziabad gave impetus to the trade and industrial activities.

7.2. Urban Development and Planning

The planned development of Ghaziabad City began way back in 1958, when the State Government issued notification to declare development (regulated) area and subsequently in another notification in 1977, Ghaziabad and 137 villages in its surroundings were declared as Ghaziabad Development Area (GDA). The development area of Ghaziabad today is 452 sq. km. The development of Ghaziabad could be seen as the influence of nearby city/town. During 1950-60 decade, Ghaziabad was perceived as satellite

town in Master Plan of Delhi, MPD-1962 and it was envisaged to be developed as satellite town, however during 1960-80, the industrial development gave it as an image of industrial township. However, with the close proximity with Delhi, it has been deeply influenced by the developments of NCT Delhi. The development in Ghaziabad especially the Trans-Hindon area can also be seen as metropolitanisation of fringe areas of a large city. With the UP (Uttar Pradesh) sub region, in addition to Ghaziabad, NOIDA and Greater NOIDA have also developed since 1980's and late 1990's. The development of these towns to some extent had distributed the population on one hand but also on the other hand there has been distribution of economic activities.

Ghaziabad is one of the important industrial center of UP sub region which has iron and steel manufacturing units, ceramics, pipe, vegetable oils, picture tube, medicine, beverages. The heavy and large-scale industries are developed in Trans-Hindon areas abutting G.T. Karnal Road, center of Link Road/Bulandshahr Marg. The small and medium industries have been developed in the Industrial Estates at Meerut Road, Kavi Nagar Industrial Estate and Loni Road Industrial estate. The number of industrial workers in Ghaziabad was 5876 in 1961, which increased to 30338 in 1981 and 54558 in 1991. The number of industrial units was 124 in 2000 and declined further to 109 in 2003. Similarly, number of small and medium industrial units was 13720 in 2000 wherein 71245 workers were engaged and increased to 15848 in 2002 with 87832 workers. The main reasons behind increase in small and medium industrial units in Ghaziabad is due to recent shifting of polluting industries from NCT Delhi.

8. Urban Land Use Trends and Patterns

With the increase in population, the residential areas have seen tremendous increase, however, the pace of development could not match the provisions for both physical and social infrastructure and services as per the requirement of the growing population. It has been observed in the context of urban landuse pattern that there is exorbitant increase in land prices (for plotted houses), which has led to the development of multi-storied apartments (Group Housing) residential units. The Trans-Hindon areas especially Shalimar Garden, Ramprastha, Kaushambi,Vaishali, Rajender Nagar have witnessed large scale construction of group housing flats even on the plots with size of 500 sq. mt. 1000 sq. mt. This development has by and large been in an unauthorized manner thereby resulting in extreme strain on infrastructure / facilities and services. The areas meant for plotted development where 2 to 3 dwelling units are supposed to be developed has

been converted into multiple dwelling units (15-20) on a plot of 500 sq. mt. to 1000 sq. mt. The high rise high density not only alters planning principles drastically but have serious adverse repercussions on the overall city infrastructure and any up-gradation or augmentation of the same is offset by multifold increase in the dwelling units and with consequent problems of low level of access to basic infrastructure like absence of drainage and sewerage, shortage of drinking water, absence of proper solid waste management etc. resulting in deteriorating quality of life.

The development of Trans-Hindon areas without any consideration of planning for basic facilities have in fact led to mushrooming of large number of residential colonies at the periphery of NCT Delhi. The decade of 1970's has also witnessed the decline of developed industrial areas due to economic liberalization and impingement of other uses on industrial areas have increased alarmingly with invasion of development of commercial activities like Shopping Malls and Multiplexes. With the increase of privatization of education, the educational and technical institutions have also sprung up all over in Ghaziabad. These institutions have largely came up on land acquired from agricultural use and some industrial areas have been converted into the usage of educational and institutional area development.

Land Use Categories				
Forest Cover:				
Dense Forests				
Open Forests				
Plantations				
Arable/ Agriculture Land:				
Cultivated Area				
Urban Land:				
Built-up Area				
Un-built-up Area				
Transport Network:				
Road/Rail Network				
Water:				
River				

Canals/Water Body				
Miscellaneous Land:				
Waste Lands				
Total				

Source: Based on Landsat and IRS satellite imagery.

Table-3. Urban land use classification of the study area.

8.1. Process of Planned Development

The First Master Plan for Ghaziabad was prepared in 1961 with a perspective of 1981. In 1961, the area of the city was 57.37 sq. kms. In Master Plan-1981, about 58.53 sq. kms. was proposed for development, however against this only 43.65 sq. kms (74.60 per cent) was developed. The next Master Plan notified in 1986 in which the total developed area was 59.33 sq. kms while the Master Plan-2001 proposed 100.39 sq. kms. as developed land. In actual terms only 84.55 sq. kms. (84.21 per cent) was developed area and the category-wise breakup can be seen in the following *Table-4*.

Sl. No.	Land use Category	Area (in sq. km.)	Area (in percentage)
1.	Residential	46.70	55.05
2.	Commercial and Trade	02.74	03.22
3.	Industrial	17.10	20.16
4.	Office	02.80	03.30
5.	Community Facilities	02.53	02.98
6.	Green Belt-Park, Open Space, Recreational Areas	03.99	04.70
7.	Undefined Areas	00.16	00.19
8.	Railways	02.32	02.73
9.	Roads/Bus Stands/ Depots	05.20	06.13
10.	Others	01.29	01.52
	Total	***84.55***	***100.00***

Source: Master Plan of Ghaziabad 2021, Ghaziabad Development Authority, Uttar Pradesh, Ghaziabad.

Table 4. Existing urban land use classification for Ghaziabad City 2003.

As per the Master Plan of Ghaziabad, MPG-2021 the total development area of Ghaziabad is 84.55 sq. kms. of which 46.70 sq. kms is under residential use constituting 55.03 per cent of the developed land. This is followed by industrial use (20.16 per cent) and 6.13 per cent use under the roads, bus stands. These three uses together constitute more than three-fourth of the total land use of the city. Among the entire uses category both residential and industrial uses have witnessed intensive development. The land under residential use was 16.48 sq. kms. in 1961, which increased to 31.60 sq. kms. in 1984 and 46.70 sq. kms. in 2003. This signifies that the increase in area under residential use in about 40 years has been 2.8 times. As far as industrial development is concerned, the 1961-81 period witnessed expansion, as the city was perceived as industrial town with 0.91 sq. kms of land developed per year. However, the 1991-2001 period has not witnessed industrial development as many industrial units got closed down due to number of prevailing reasons like shortage of water and power and other supporting infrastructure facilities. Further, the focus of industrial development in UP sub region shifted to NOIDA and Greater Noida with the establishment of separate industrial development authorities for the two towns. There is further possibility of setting up of new industries as there has been shifting of polluting units from NCT Delhi.

9. Conclusions

Consequently, the increasing pace of urban sprawl has resulted into the large scale agriculturally productive land conversion into the concrete jungle or built-up area. The agricultural land resource is under stress due to the increasing pressure of population. This has resulted into widespread destruction of the fertile agricultural land and natural vegetation as well as the shrinkage of 'green cover' in the study area. However, for sustainable development the authorities need tools to monitor how the land is currently being used, assess future demand, and take steps to assure adequacy of land for future development. In other words, the development authorities need to know urban sprawl phenomenon and in which way it is likely to develop in the near future. So, there is a need for better planning of infrastructure and amenities for urban development.

Over the periods, there has been a continuous process of urban sprawl in the rural-urban fringe due to the liberalization of economy, development plans and policies of the State Govt. and Central Govt. of India. There have

been establishments of number of national and multinational companies which have resulted into the continuous urban sprawl in the NCR Region. On the other hand, it has resulted into the rise of land values not only in Delhi but also in the NCR region. There has been increasing pace of urban sprawl which has resulted into the large scale agriculturally productive land conversion into the concrete jungle or built-up area. The agricultural land resource is under stress due to the increasing pressure of population. This has resulted into widespread destruction of the fertile agricultural land and natural vegetation as well as the shrinkage of 'green cover' in the study area.

10. Recommendations

It is noteworthy to mention that in the sub-region NCR of the Uttar Pradesh State the pace of urban sprawl was much faster due to the govt. development plans and policies than in the other participating states of the NCR Region. Moreover, the present research would make an attempt to help local, regional and state level land use planners and policy makers to better understand and address the issues attributed to urban sprawl. Therefore, the urban expansions are to be planned over the non-fertile agricultural land for sustainable urban and environment development which are the most important concerns for the new urban sprawling areas in the NCR Region at the threshold of the 21st Century.

The city has its own problems and often comes under the shadow of Delhi metropolis and unable to realize its own potential. Some of the major planning and developmental problems of Ghaziabad City are as (i) the separate identity of Ghaziabad is somewhat diluted under the shadow of NCT Delhi thereby the city has not been able to come up as self induced bustling urban center in NCR; (ii) the economic base with declining industries and new economic activities coming-up in unplanned manner has disturbed the physical development of the city; (iii) unauthorized colonization on agricultural land has resulted in unauthorized and uncontrolled development wherein there is an absence of basic infrastructure facilities and on the other hand it gives rise to numerous problems for planned development like regularization of colonies and augmentation of infrastructure services / facilities thereof. Further, lack of strict enforcement of Building Bye Laws and Master Plan provisions has also been responsible for haphazard development (iv) prevalence of non-conforming landuse mainly in terms of offices, schools, hospitals, shops located in residential premises; (v) excessive congestion on major arterial road for example Ambedkar Road and GT Road. Further due to absence of planned parking spaces, on-road parking

of trucks, buses and other vehicles has created serious traffic and transportation problems. Above all encroachment by rehris, kiosks and thelas have further worsened the intra-traffic movement in the city; (vi) absence of proper solid waste management has caused dumping of wastes into pits thereby resulting in pollution of land, air and water resources; (vii) uneven distribution of water supply, absence of sewage system and drainage system has added to the woes of city infrastructure; (viii) absence of common Effluent Treatment Plan in the industrial areas of the city has led to mixing of chemical effluents, which has ultimately polluted the Hindon River and ground water resources; (ix) indiscriminate exploitation of ground water has led to drastic fall in the level of ground water.

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